

Atlantic Richfield Company

Anthony R. Brown
Project Manager, Mining

4 Centerpointe Drive
La Palma, CA 90623-1066
Office: (714) 228-6770
Fax: (714) 228-6749
E-mail: Anthony.Brown@bp.com

March 1, 2012

VIA EMAIL

Mr. Steven Way
On-Scene Coordinator
Emergency Response Program (8EPR-SA)
U.S. EPA Region 8
1995 Wynkoop Street
Denver, CO 80202-1129

RE: Submittal of Rico Flood Dike Interim Flood Dike Upgrades Technical Memorandum – Rico Tunnels Operable Unit OU01, Rico, Colorado EPA Unilateral Administrative Order, Docket No. CERCLA-08-2011-0005

Dear Mr. Way:

A digital file in pdf format of the Technical Memorandum (TM) titled “Interim Flood Dike Upgrades Technical Memorandum – Rico Tunnels Operable Unit OU01, Rico, Colorado” dated March 1, 2012 is being submitted to you today via email from Doug Yadon at AECOM. Three (3) hard copies of the report will be hand-delivered to your office on March 2, 2012.

Atlantic Richfield Company (AR) is submitting this TM responsive to Section 6.0 Recommendations of the report titled “2011 Investigations, Analyses and Evaluations, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado.”

Copies of letters of notification to the U.S. Army Corps of Engineers and the Dolores County Board of County Commissioners applicable to the work under this TM and responsive to the action- and location-specific ARAR’s per Section 7.0 of the Removal Action Work Plan will be submitted to EPA under separate cover not later than March 5, 2012.

If you have any questions or comments, please feel free to contact me at (714) 228-6770 or via email at Anthony.Brown@bp.com.

Sincerely,



Tony Brown
Project Manager
Atlantic Richfield Company

Anthony R. Brown

March 1, 2012

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Enclosures

cc: J. Christner, URS
 T. Moore, AR
 A. Cohen, DGS
 S. Reise, ENSci
 C. Sanchez, AECI
 T. Kreutz, AECOM
 D. Yadon, AECOM
 E. Gleason, AECOM



To Tony Brown/AR

cc Terry Moore/AR; Chris Sanchez/AECI

Interim Flood Dike Upgrades Technical Memorandum – Rico Tunnels
Operable Unit OU01, Rico, Colorado EPA Unilateral Administrative Order,
Docket No. CERCLA-08-2011-0005

From Douglas M. Yadon/AECOM; Erin Gleason/AECOM

Date March 1, 2012

1.0 Purpose

AECOM, in cooperation with Anderson Engineering Company, Inc. (AECI) and on behalf of Atlantic Richfield Company (AR), has prepared this Technical Memorandum (TM) describing the final analysis and design for interim flood dike upgrades at the Rico Tunnels Operable Unit OU01 of the Rico-Argentine Mine Site pursuant to Subtask B3 of the Removal Action Work Plan. This TM supplements the analyses provided in Part B of the report titled *2011 Investigations, Analyses and Evaluations* (AECOM, 2011) (hereinafter referred to as the 2011 Report).

Preliminary hydraulic analyses were originally summarized in Section 2.0 of the 2011 Report. This TM presents the results of refinements made to the 2011 hydraulic model to better quantify the velocities at the upstream end of the flood dike in the secondary side-channel. Planned interim upgrades based on the updated hydraulic model results are provided in Section 4.0 of this TM. Figures included at the end of this TM are based on the updated hydraulic model results and riprap design analyses and provide the basis for the design drawings and technical specifications that will be submitted to EPA by AR not later than March 1, 2012. The overall site plan is shown on Figure 1.1.

2.0 Hydraulic Model

Further evaluation of the modeled flood dike reach north of Station 36+00 (see Figure 1.1) was identified in the 2011 Report to more accurately quantify the velocities in the secondary side channel in this area. The riprap sizing and velocities estimated for the 100-year flow event presented in the 2011 Report were considered conservative in the secondary side channel as explained in the 2011 Report. HEC-RAS model refinement and results are described below.

2.1 Model Refinement

The HEC-RAS model presented in the 2011 Report was adjusted to more accurately model the split flow along the 1,145-foot long segment of the Dolores River between Station 49+70 and Station 38+25. Modifications were made so that the main channel and the side channel between these stations were modeled as two parallel but separate river reaches connected by a series of lateral overflow weirs. This was done by adding junctions to optimize the flow at the upstream and downstream stations of the split. A side channel river reach was added between the junctions and the cross sections were copied to the new reach. The original cross sections that included both the main channel and the secondary side channel were split at the existing berm location separating the two channels. A series of broad crested weirs all with a weir coefficient of 2.62 were placed at the top of the berm between each cross section, allowing water to flow between the two channels to optimize the split of flow along the length of the revised reach.

To more accurately represent variation in velocity across the channel, the modeled bank stations were adjusted from those in the original model which were located at the approximate actual river bank and instead set to the 25-year flood event water surface elevation in all cross sections in the HEC-RAS model. This change resulted in a more even velocity distribution across each cross section, requiring less iterations for the model to balance the flow, indicating a more accurate representation of the flow conditions. Minimal change in the modeled water surface elevation and velocity resulted from this refinement.

No additional data were collected and no changes, other than those described above, were made to the HEC-RAS model presented in the 2011 Report.

2.2 Hydraulic Model Results

Velocities for the various reaches of riprap analysis based on the revised model are reported in Table 2.1. The inundation maps (Figures 2.1 through 2.4) show the inundation polygons for the 100-year floodplain on the aerial imagery flown in August 2011. Although the inundation area near cross section 49+30.4 on Figure 2.1 shows flow on the upstream side of the man-made dike, no riprap is required in this zone because: 1) the velocities in the main channel of this cross section (2.1 ft/s) are too low to erode the embankment material; and 2) the flow against the dike is backwater flow and velocities will be even lower than those in the main channel. All maps are plotted at a scale of 1inch = 100 feet, and are in the Colorado State Plane coordinate system (central zone) with elevations based on NAVD88.

3.0 Riprap Analysis

Preliminary riprap analyses were presented in the 2011 Report. Suitability of the existing riprap was re-examined based on the revised HEC-RAS model described in Section 2.0 of this TM. The preliminary and current analyses were conducted between Station 11+00 (Pond 5) and Station 47+00 at the upper end of the site. The area of the analyses is depicted in plan view on Figure 1.1. Both preliminary and current analyses included an evaluation of stone sizing, revetment toe scour, bank slope steepness, riprap layer thickness and gradation, filter gradation and thickness, and riprap freeboard.

3.1 Methodology

The same methodology used in the riprap adequacy analysis presented in the 2011 Report was used for the current analysis of riprap adequacy. Similarly, the same criteria for riprap and toe scour designs used in the analyses presented in the 2011 Report were used for the interim upgrades design documented herein. Further information on the methodology can be found in Part B of the 2011 Report.

The existing revetment was subdivided into a series of reaches with similar characteristics, as described in the 2011 Report. Reach extents and typical characteristics are summarized in Table 3.2.

Velocity information for the updated evaluations reported herein was obtained from the revised HEC-RAS model discussed in Section 2.0. Between Station 49+70 and Station 38+25, the velocity information for the secondary side channel, or left channel, was used for the analyses.

The top of riprap is typically set above the design flood to provide freeboard to accommodate various unavoidable uncertainties. Guidelines from the Transportation Research Board recommend 2.0 feet of riprap freeboard (Lagasse, et al., 2006), and this is adopted as the design freeboard criterion for the flood dike.

3.2 Results

The existing riprap revetment has been subdivided into the same series of standard reaches for purposes of these analyses as were used in the 2011 Report to group areas of similar characteristic riprap size. Key analysis inputs and results are presented in Table 3.1 for every even 100-foot station in the area of interest.

3.2.1 Adequacy of Bank Slope. Bank slope was taken from field measurements presented in the 2011 Report. Between Stations 34+00 and 38+00, the existing bank exceeds 1.5H:1V bank steepness guidelines discussed previously in Section 3.1.3 of the 2011 Report. As discussed in the following section, this reach is believed to contain buried riprap which may or may not be of adequate slope and/or size.

3.2.2 Adequacy of Riprap Size. The riprap adequacy was evaluated using criteria presented and discussed in the 2011 Report. For all stations, the adjusted bank velocity computed using the velocity, curvature and width of the main central channel was critical, and these velocities and curvatures are presented in Table 3.1, along with existing bank slope and computed bank velocity. A comparison of existing riprap size (D_{30} , or the particle sieve size 30 percent of stones are smaller than) versus the minimum size computed from the riprap size analyses described previously, and a safety factor computed from the ratio of these two sizes, are also presented. As discussed below and illustrated in Table 3.1, the results indicate that several areas along the Ponds 15 and 18 portions of the flood dike do not meet an EM1110-2-1601 recommended minimum Safety Factor of 1.1.

The reach alongside Ponds 15 and 18 may contain buried riprap based on test pits and the original construction documentation. The size utilized in the analyses,

however, was based on the approximate gradation of the visible surface materials, which are substantially finer. These surface materials are likely to be stripped away in the design flood leaving riprap of mostly unknown size, quality and bank slope. Additionally, the existing bank slope in this area is over-steepened beyond the adopted design criterion (underlying riprap may or may not be over-steepened) and will be flattened as described later.

- 3.2.3 Adequacy of Riprap Gradation, Stone Characteristics and Thickness.** As discussed in the 2011 Report, riprap was visually observed to be of good quality, and has generally withstood the elements well. The stones are predominantly angular, as recommended by design guidelines as discussed previously. No data were collected on stone shape relative to riprap design guidelines, but qualitative visual observation of the riprap indicates that stone shape is not deficient. Furthermore, this is not a major factor in revetment stability, nor does it appear to have resulted in any stability issues in the life of the revetment to date.

D_{85}/D_{15} ratios of the existing riprap computed from field grid data (Figures 4.1 to 4.3) are presented in the 2011 Report and in Table 3.2. Except in areas where the materials exposed on the flood dike slope are deficient in terms of riprap sizing as described in the previous section (Reaches 3 and 4, Ponds 15 and 18, see Figure 1.1), results generally indicate that the riprap falls within or nearly within gradation guidelines presented in the 2011 Report, which lists D_{85}/D_{15} ratios of 1.4-2.2 and 1.5-2.5 for the Corps of Engineers and Transportation Research Board guidelines for narrowly graded riprap, respectively. Reach 1 has been noted to contain an excess amount of smaller stones in some areas (such as Grid 2 at Station 41+00), which generally reduces the computed D_{30} size and results in a wider gradation. At Grid 2, the estimated D_{85}/D_{15} ratio of 7.9 falls just outside the Corps of Engineer's maximum recommended ratio of 7 for quarry-run stone. In Reach 5, Grid 7C (Station 27+95), the field survey noted a very localized small pocket of stones composed partially of shale which appears to have broken down, causing both the D_{30} stone size to be reduced and the gradation to widen, but this area is not considered characteristic of the reach. Any such localized areas will be identified and supplemented during the construction of final dike upgrades as discussed in Section 4.0.

The originally designed layer thickness of the riprap revetment was 24 inches, and test pits conducted as part of the 2011 field investigations generally indicated that the riprap layer is nominally 24 inches thick. The thickness does not, however, generally meet the layer thickness criterion adopted for the project as discussed in the 2011 Report. In many areas, however, the riprap has a very large safety factor and the riprap layer is judged more than adequate to resist the design flows. A 24-inch layer thickness would be appropriate for a D_{50} size of 16 inches or less and a D_{30} size of 13.3 inches or less. From Table 3.5 in the 2011 Report, Reaches 1 and 2 meet this thickness criterion, whereas Reaches 5 and 6 do not. Except for Stations 20+00 and 21+00, Reaches 5 and 6 require riprap much smaller than 13.3 inches according to the analyses presented in Table 3.1. It is concluded that because the riprap is significantly oversized, the thinner than criterion riprap sections in Reaches 5 and 6 will be stable under the 100-year flood flows.

3.2.4 Adequacy of Bedding Gradation and Thickness. The results of gradation analyses of the filter materials beneath the riprap layer are presented in the Appendix to this TM. D_{85} is calculated for each gradation for comparison to the D_{15} of the riprap to check filter compatibility of the two layers. The D_{85}/D_{15} ratio should be less than 4 to 5, using the criterion in EM 1110-2-1601. Many of the surface gradations were collected in reaches 3 and 4 (Stations 33+00 – 36+90) where riprap is either not present or is buried, so a direct comparison could not be made. As discussed later, this area is recommended for interim upgrade for various reasons discussed in previous sections, including steep bank angle and inadequate gradation of riprap on the bank surface. As indicated in Table 3.2, in other areas, the D_{85}/D_{15} ratio meets the design criterion.

3.2.5 Adequacy of Toe Scour Protection. The methodology to assess potential scour of the existing river bed material that could impact stability of the riprap is presented in Part B, Section 5.1 of the 2011 Report. Estimated scour depths for the best estimate case (Case 1) and estimated worst case (Case 2) assumed streambed armoring scenarios are presented in Table 3.1. For both cases, very little streambed scour is expected to occur. Results shown in Table 3.1 indicate that in Case 2 estimated worst-case scour will not extend below the existing river cobbles.

4.0 Interim Flood Dike Improvements

The interim flood dike stability upgrades prioritized and presented here and in Table 3.1 are based on analyses subdividing the flood dike into characteristic reaches. As noted above, within a given reach there may be small, localized areas that may require maintenance or are substandard relative to the assigned characteristics of the reach (smaller riprap size, damage, etc.). Final flood dike upgrades will include provisions for localized maintenance or repair based on further field observations and final design work to be completed during 2012.

Design drawings and technical specifications based on the design presented herein will be prepared for contractor procurement and construction of the improvements. Interim upgrade measures are provided in the individual sections below and summarized in Table 3.1.

4.1 Pond 15/18 Revetment (Stations 29+50 to 38+50)

This section of revetment will be reconstructed due to the lack or inadequacy of riprap and/or oversteepened slope which exceeds the recommended 1.5H:1V maximum inclination between Stations 33+15 to 35+20 and Stations 36+50 to 38+50. Where the reconstructed riprap cannot be founded directly on the river bottom cobbles and is instead founded on overbank deposits, a launch section will be included to protect from potential scour of the overbank deposits. Riprap size will be Class III (12-inch nominal D_{50} size) resulting in a 24-inch layer thickness per the design criterion described in the 2011 Report. A filter is provided to underlay the riprap where it is in contact with embankment fill. Final selection of a compatible filter is underway and will be included in the final Interim Flood Dike Upgrades Drawings and Technical Specifications.

In other areas outside the two ranges identified above but within this overall reach (Stations 29+50 to 33+15 and 35+20 to 36+50) as determined by AECOM in the field, the existing riprap in localized areas will be supplemented to provide compatibility with the revetment design described above where riprap is deemed too small or is missing. In addition, the existing dike crest in two areas from Stations 30+70 to 33+15 and 35+20 to 36+50 will be raised to establish a minimum of 2.0 feet of riprap freeboard as discussed in Section 3.1. A plan and profile and typical sections of the planned upgrades are provided on Figures 4.2, 4.3, 4.5 and 4.6.

4.2 Pond 15 and 18 Seeps

Two known seeps, P-15-S and P-18-S as indentified on the plan view of Figures 4.2 and 4.3, respectively, will be addressed as part of the interim flood dike upgrades since they lie within the boundaries of the planned work. These seeps will be provided with additional granular filter protection against piping as well as adequate drainage capacity to dissipate seepage pore pressures. The final drawings and technical specifications will include provisions for filtration and drainage in these areas, likely consisting of a typical detail that includes an additional filtration layer beneath the riprap filter and potentially a finger drain. The exact extent and location of these features will be as determined by AECOM in the field during construction and will be established once equipment is on-site and available to uncover the specific location, extent and nature of the seepage.

4.3 Pond 9 Revetment (Station 19+40 – Station 21+60)

The hydraulic analysis indicates that the flood dike freeboard between Pond 11 and Pond 7 decreases from 9 feet to 0 feet (overtopping) due to an abrupt drop in the flood dike height downstream of Pond 11. Freeboard adjacent to Pond 9 will be increased to the three foot criterion for levees (Lagasse, et al., 2006). The existing riprap is adequate; however, the dike crest will be raised slightly to provide the necessary flood freeboard from Stations 19+40 to 20+00 and Stations 21+00 to 21+60. A plan and profile and typical sections of the upgrades are provided in Figures 4.1 and 4.4.

5.0 References

AECOM. 2011. 2011 Investigations, Analyses and Evaluations, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado. December 30.

Lagasse, P.F., Clopper, P.E., Zevenbergen, L.W., and Ruff, J.F. 2006. Riprap Design Criteria, Recommended Specifications, and Quality Control, NCHRP Report 568, Transportation Research Board, National Academies of Science, Washington, D.C.

TABLES

Table 2.1 - HEC-RAS Results

HEC-RAS Station	Q Total	Invert Slope	Water Depth	Average Cross Section Velocity	Main Channel Velocity	Froude
	(cfs)	(ft/ft)	(ft)	(ft/s)	(ft/s)	
956.1						
54+44.5	2200	0.0081	6.37	5.26	5.26	0.48
53+51.9	2200	0.0171	4.67	6.3	6.3	0.63
52+72.5	2200	0.0215	4.71	5.48	5.48	0.55
51+94.5	2200	0.0216	5.18	6.03	6.03	0.61
51+04.5	2200	0.014	5.54	7.21	7.21	0.72
50+30.0	2200	0.0151	5.41	6.27	6.27	0.66
49+30.7	950.88	0.02	5.4	2.23	2.23	0.22
48+35.7	1473.02	0.0235	5.76	2.14	2.16	0.19
47+50.6	1345.4	-0.0161	6.83	2.07	2.08	0.17
46+60.7	998.77	0.0296	5.42	3.74	3.74	0.35
45+51.3	696.68	0.0348	5.64	2.89	2.89	0.26
44+26.5	1308.32	-0.0417	7.89	2.7	2.7	0.21
43+24.3	1314.44	-0.0016	6.82	3.6	3.6	0.31
42+14.0	1317.42	0.0081	6.21	3.2	3.2	0.3
39+75.4	1403.94	-0.0155	5.8	2.31	2.31	0.21
38+25.6	873.56	0.0652	4.11	1.72	1.72	0.17
36+21.3	2200	0.0161	5.63	4.49	4.63	0.44
34+48.0	2200	0.0137	5.26	3.04	3.51	0.33
32+30.9	2200	0.0175	5.05	3.62	3.62	0.34
30+17.4	2200	0.0188	5.44	2.85	2.85	0.24
26+91.7	2200	0.0185	7.24	4.26	4.26	0.33
24+64.6	2200	0.0139	8.91	2.55	2.55	0.18
22+13.0	2200	0.014	8.43	5.46	5.46	0.42
20+44.8	2200	0.0264	5.02	7.57	7.57	0.78
18+99.0	2200	0.0134	6.63	4.32	4.32	0.39
17+56.2	2200	0.0102	5.61	5.02	5.02	0.54
15+12.4	2200	0.0222	3.81	4.44	5.37	0.58
13+23.4	2200	0.0165	4.32	5.05	5.88	0.65
11+11.1	2200	0.0237	3.85	4.33	5.57	0.64
9+17.0	2200	0.0108	4.76	3.47	4.12	0.44
6+64.1	2200	0.0147	4.42	2.77	4.6	0.47
4+08.4	2200	0.0152	5.27	3.05	4.23	0.39
1+51.2	2200	0.0111	7.27	3	3.03	0.25
0+12.2	2200	0.0103	7.26	7.67	7.67	0.65
-0+46.3	2200	0.0089	6.59	10.04	10.04	0.99
-2+56.9	2200	0.0062	3.97	2.64	3.57	0.36
-5+64.4	2200	0.0167	5.03	3.36	3.36	0.32

Table 3.1 Riprap Analysis Model Results and Recommendations

Feature	Station	Channel Parameters			Existing Bank Slope	Bank Riprap Analysis Velocity (ft/s)	Subcritical / Supercritical Transition Zone?	Riprap D30 (inches)			Safety Factor (Minimum 1.1 Recommended)	Estimated Scour (ft)		Recommendations for Interim Stabilization
		Slope (%)	Channel Velocity (ft/s)	Curvature (Width / Radius); + = outside bend				Characteristic Riprap Reach	Minimum Required (SF=0)	Estimated Existing		Case 1 - Best Estimate	Case 2 - Worst Case	
Upper Area	47+00	1.0%	3.0	0.04	2.1	3.7	No	1	2.7	13.0	4.9	0.0	0.0	No Action
	46+00	3.2%	3.3	0.07	2.1	4.0	No		7.6	13.0	1.7	0.0	0.0	
	45+00	0.3%	2.8	0.07	2.1	4.6	No		1.6	13.0	7.9	0.0	0.0	
	44+00	-3.1%	2.9	0.07	2.1	5.2	No		1.1	13.0	11.4	0.0	0.0	
	43+00	0.1%	3.5	0.07	2.1	5.0	No		1.1	13.0	12.1	0.0	0.0	
	42+00	0.7%	3.1	0.07	2.1	4.8	No		1.0	13.0	13.4	0.0	0.0	
	41+00	-0.3%	2.8	0.07	2.1	4.4	No		0.8	9.4	11.9	0.0	0.0	
Pond 18	40+00	-1.3%	2.4	0.07	1.9	4.2	No	2	0.8	9.4	12.2	0.0	0.0	Reconstruct reach with maximum 1.5H:1V slope and adequate riprap size
	39+00	2.5%	2.0	-0.06	1.7	2.5	No		1.7	9.4	5.6	0.0	0.0	
	38+00	5.9%	2.1	-0.06	1.5	2.4	No		6.6	9.4	1.4	0.0	0.0	
	37+00	3.5%	3.5	-0.06	1.2	3.5	No		7.6	9.4	1.2	0.0	0.0	
	36+00	1.6%	4.5	0.09	2.1	4.9	No		1.2	0.4	0.3	0.0	0.0	
	35+00	1.4%	3.8	0.04	1.4	7.3	No		4.0	0.4	0.1	0.0	0.0	
	34+00	1.5%	3.5	0.08	1.4	5.6	No		2.1	0.4	0.2	0.0	0.0	
Pond 15	33+00	1.6%	3.6	0.08	2.0	5.4	No	3	1.5	0.4	0.3	0.0	0.0	Reconstruct reach with maximum 1.5H:1V slope and adequate riprap size
	32+00	1.8%	3.5	0.04	2.4	5.2	No		1.1	18.0	15.7	0.0	0.0	
	31+00	1.8%	3.1	-0.23	2.7	4.7	No		0.8	18.0	21.4	0.0	0.0	
	30+00	1.9%	2.9	-0.11	2.3	3.5	No		0.4	18.0	41.8	0.0	0.0	
	29+00	1.9%	3.4	0.04	1.9	3.4	No		0.4	18.0	43.4	0.0	0.0	
	28+00	1.9%	3.8	0.04	2.1	3.8	No		0.5	18.0	35.0	0.0	0.0	
	27+00	1.8%	4.2	0.04	1.9	4.2	No		0.7	18.0	26.5	0.0	0.0	
Ponds 11, 12 and 14	26+00	1.7%	3.6	0.04	1.7	3.6	No	4	0.5	15.0	31.7	0.0	0.0	No action
	25+00	1.5%	2.8	-0.04	1.7	3.2	No		0.4	15.0	42.5	0.0	0.0	
	24+00	1.4%	3.3	-0.04	1.7	3.3	No		0.4	15.0	39.5	0.0	0.0	
	23+00	1.4%	4.5	-0.04	2.0	4.5	No		0.8	15.0	19.9	0.0	0.0	
	22+00	1.5%	5.6	0.09	2.4	5.6	No		1.3	15.0	11.3	0.0	0.0	
	21+00	2.2%	6.9	0.09	2.7	6.9	No		10.8	15.0	1.4	0.0	0.0	
	20+00	2.2%	6.6	0.09	2.7	6.7	No		9.8	15.0	1.5	0.0	0.0	
Ponds 7, 8 and 9	19+00	1.4%	4.4	0.09	2.7	6.8	No	5	2.1	15.0	7.1	0.0	0.0	No action
	18+00	1.1%	4.8	0.04	2.7	6.9	No		2.1	15.0	7.0	0.0	0.0	
	17+00	1.3%	5.1	0.04	2.6	6.6	No		2.0	15.0	7.6	0.0	0.0	
	16+00	1.8%	5.2	-0.09	2.6	6.7	No		2.1	15.0	7.0	0.0	0.0	
	15+00	2.2%	5.4	-0.09	2.5	5.9	No		5.9	15.0	2.6	0.0	0.0	
	14+00	1.9%	5.7	0.04	2.5	5.7	No		1.5	15.0	10.1	0.0	0.0	
	13+00	1.7%	5.8	0.09	2.4	7.1	No		2.8	15.0	5.3	0.0	0.0	
Ponds 5 and 6	12+00	2.1%	5.7	0.09	2.4	9.3	No	6	6.0	15.0	2.5	0.0	0.0	No action
	11+00	2.3%	5.5	0.04	2.3	9.4	No		5.9	15.0	2.5	0.0	0.1	

Table 3.2 - Field Data Gradation Summary and Characteristic Riprap Size by Reach

Reach	Field Data Gradation Analysis Summary													
	1	2	3	4	5	6								
Field Station	~ 44+50	41+00	36+50	36+00	35+00	33+65	33+55	31+25	28+61	27+95	26+47	23+72	21+00	19+50
Model Station	44+50	41+00	36+50	36+00	35+00	33+65	33+55	31+25	28+61	27+95	26+47	23+72	21+00	19+50
Grid	1	2	3B	3C.2	3D	4B	5B	6B	7B	7C	8B	9B	E4	E5
D ₈₅ (in)	20.5	23.8	2.7	27.0	2.0	2.8	26.2	28.5	28.4	27.5	28.7	26.7	26.6	27.3
D ₅₀ (in)	16.5	15.5	0.5	18.7	0.7	0.9	16.8	22.2	21.9	18.3	22.9	19.1	18.9	19.8
D ₃₀ (in)	13.0	9.4	0.1	13.3	0.4	0.5	9.8	18.8	18.7	9.8	17.9	15.6	15.2	16.6
D ₁₅ (in)	9.5	3.0	0.0	0.7	0.1	0.3	1.1	15.5	15.5	1.6	10.3	11.1	9.8	13.2
D ₈₅ /D ₁₅	2.2	7.9*	787.6*	41.4*	29.8*	9.4*	23.6*	1.8	1.8	17.1**	2.8	2.4	2.7	2.1

* - Reach 2 to be evaluated further during Final Design; Reaches 3 and 4 to be rebuilt during Interim Stabilization

** - Reach 5, Station 27+95, Grid 7C is a localized area containing stones composed of shale that have partially broken down; area is not considered characteristic of the reach

Characteristic Riprap Size by Reach for Analysis				
Reach	Begin	End	D ₃₀ (in)	D ₁₅ (in)*
6	11+00	27+00	15.0	9.5
5	27+00	33+00	18.0	15.5
4	33+00	35+20	0.4	-
3	35+20	36+90	0.4	-
2	36+90	41+00	9.4	9
1	41+00	47+50	13.0	9.5

* - Selected conservatively for filter analysis

Color Codes

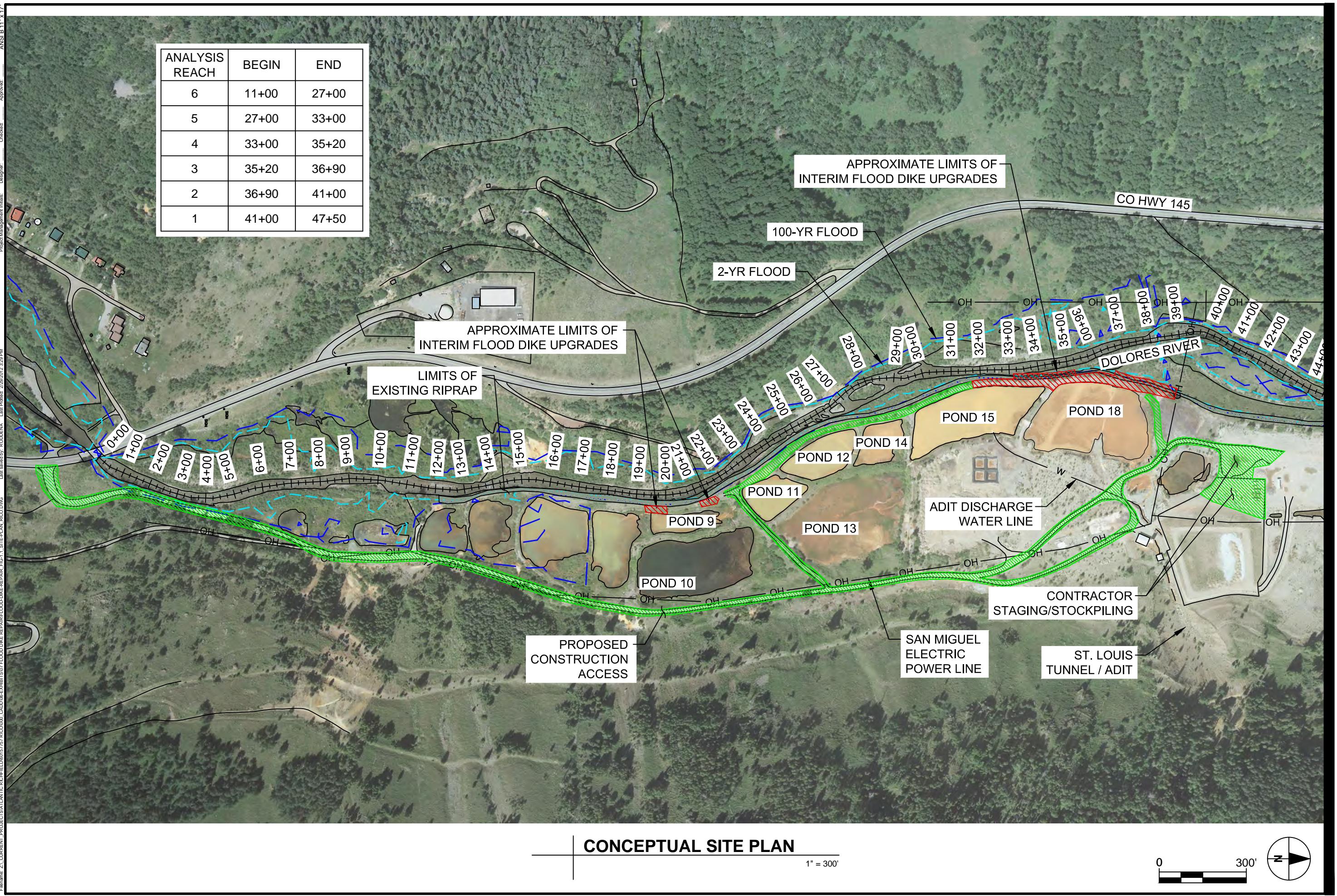
	Meets gradation criteria
	Slightly exceeds EM1110-2-1601 standard gradation criteria; meets EM1110-2-1601 quarry run gradation; to be evaluated during final design
	Does not meet gradation criteria, see notes

FIGURES

RICO-ARGENTINE SITE-OU01

INTERIM FLOOD DIKE UPGRADES - CONCEPTUAL SITE PLAN

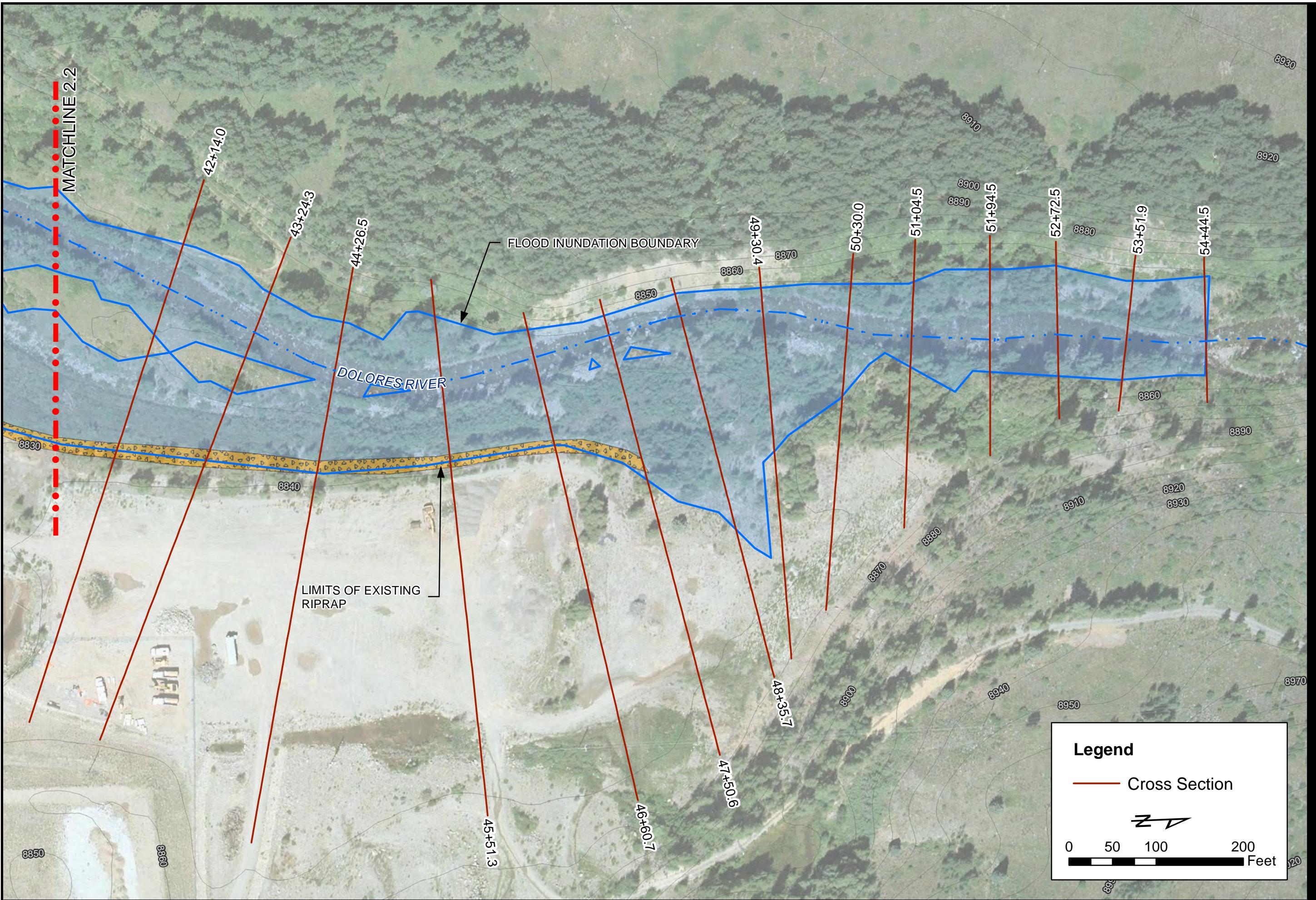
FIGURE 1.1



RICO-ARGENTINE SITE

DOLORES RIVER 100-YEAR FLOOD INUNDATION

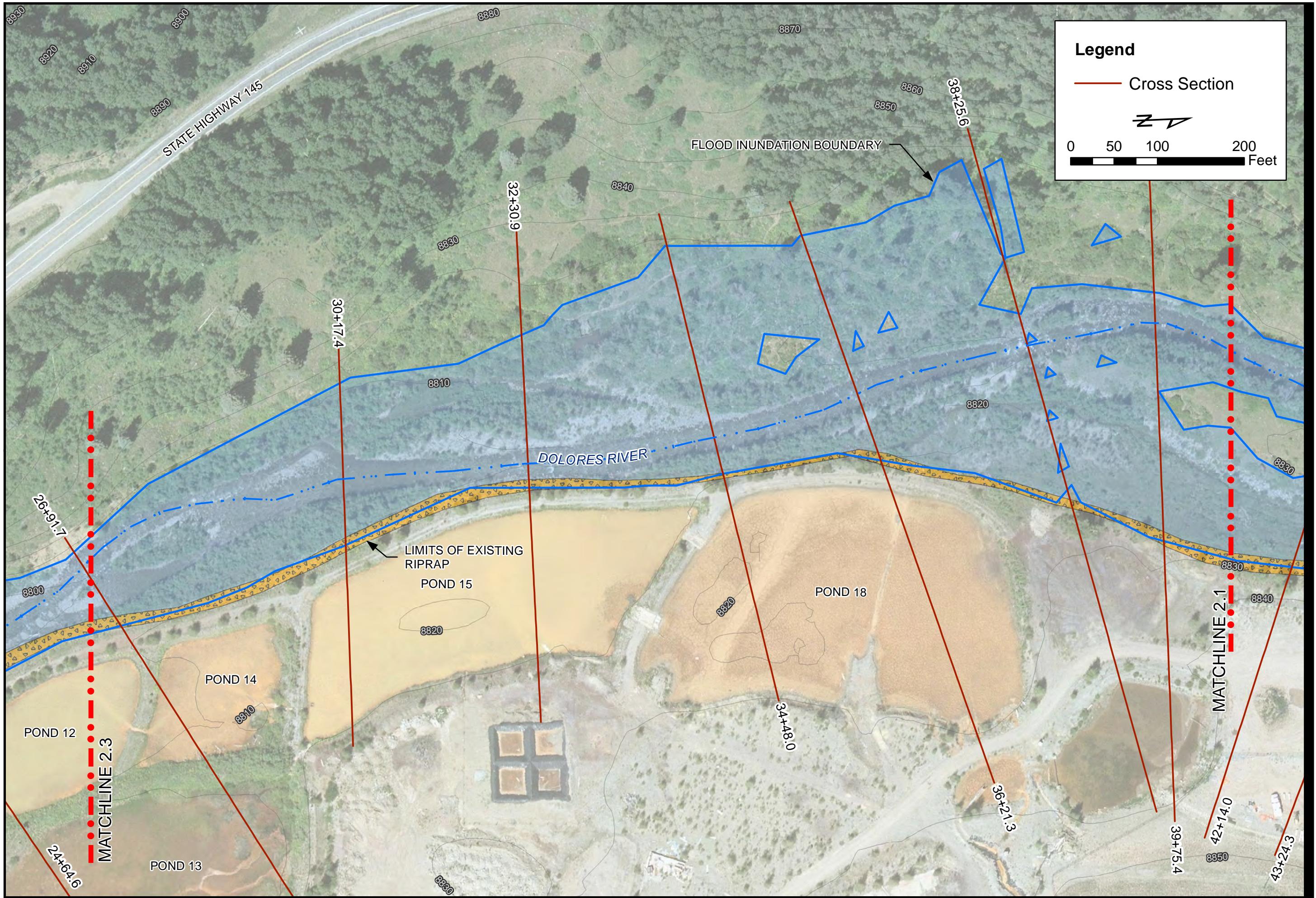
FIGURE 2.1



RICO-ARGENTINE SITE

DOLORES RIVER 100-YEAR FLOOD INUNDATION

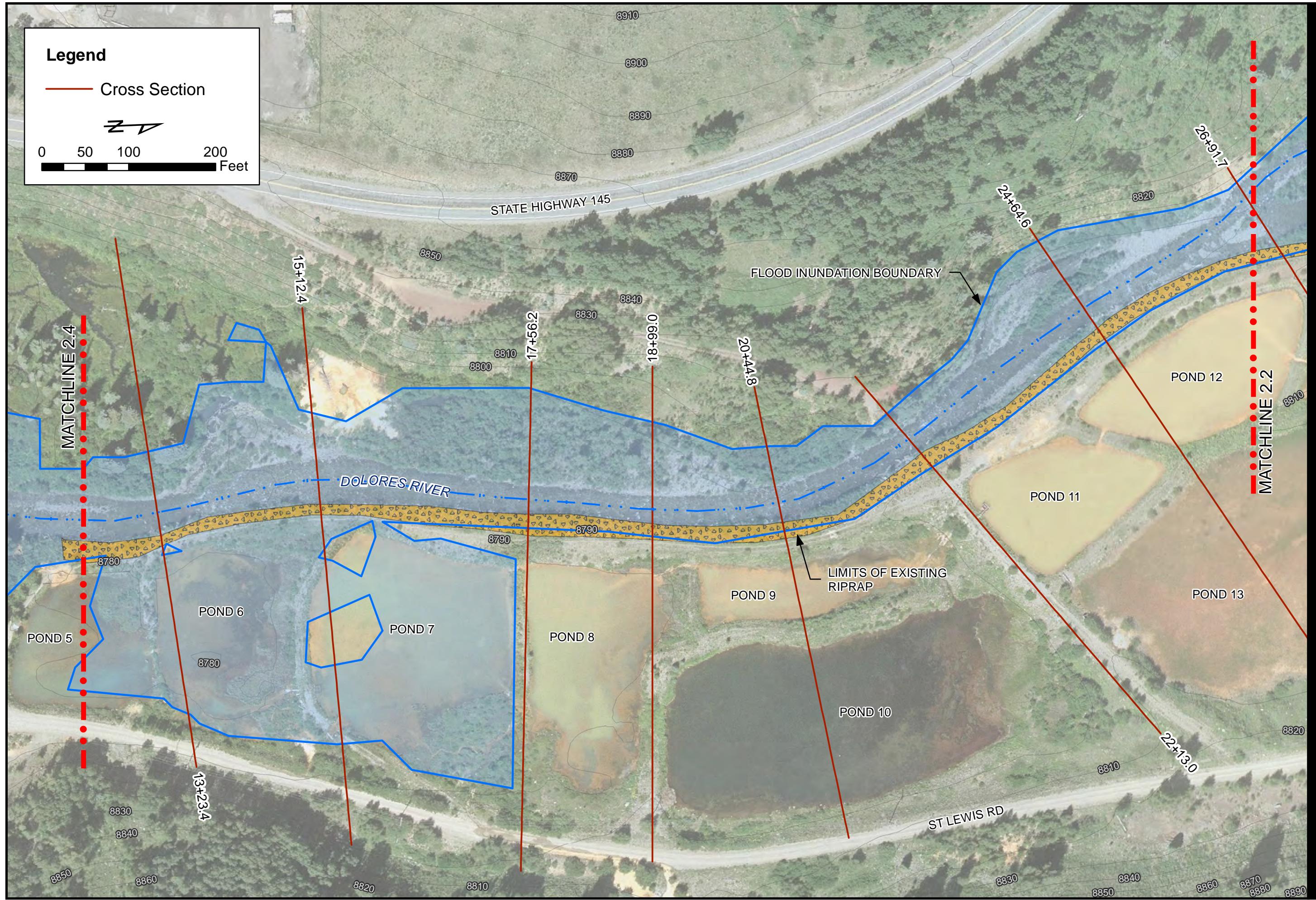
FIGURE 2.2



RICO-ARGENTINE SITE

DOLORES RIVER 100- YEAR FLOOD INUNDATION

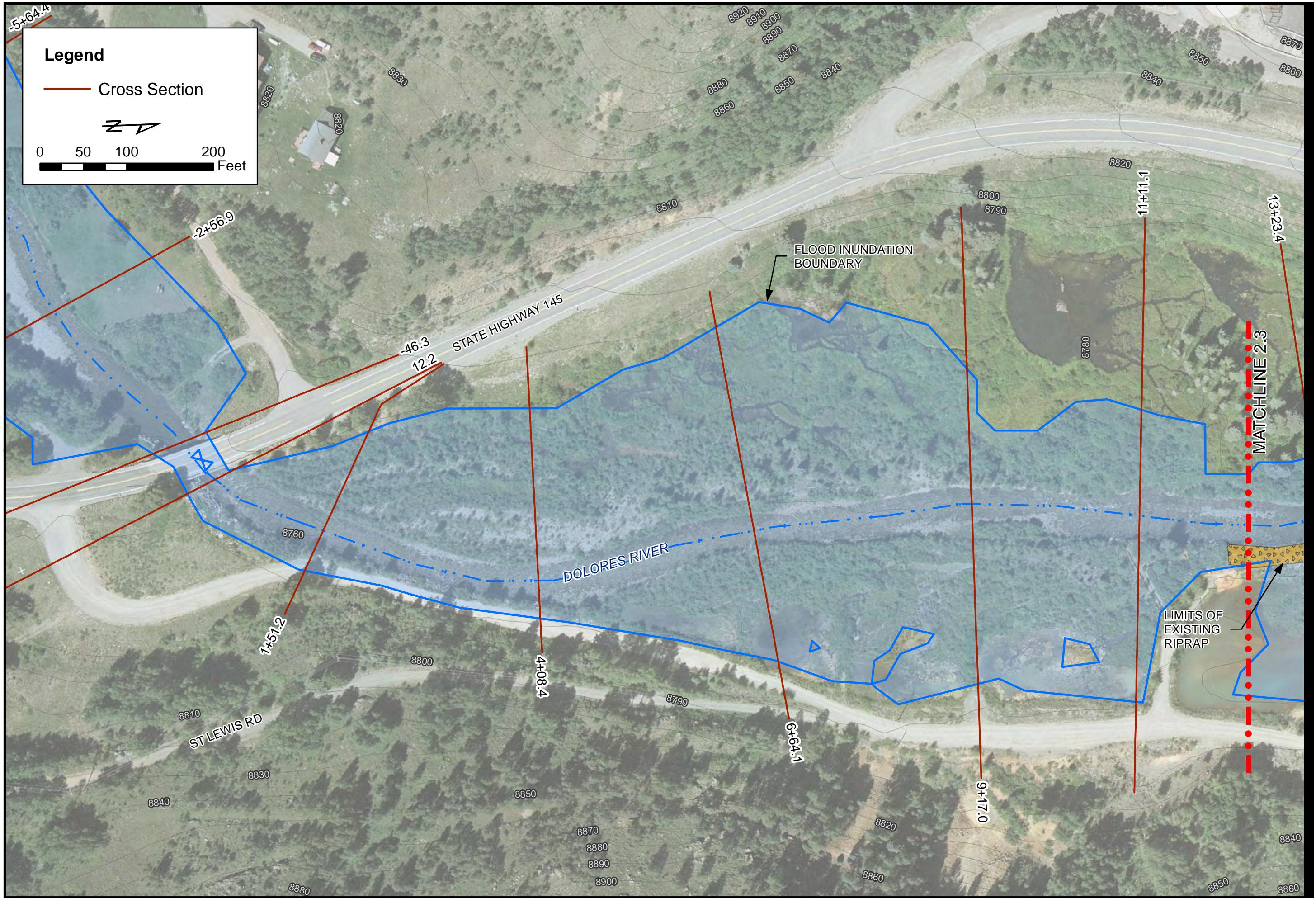
FIGURE 2.3



RICO-ARGENTINE SITE

DOLORES RIVER 100-YEAR FLOOD INUNDATION

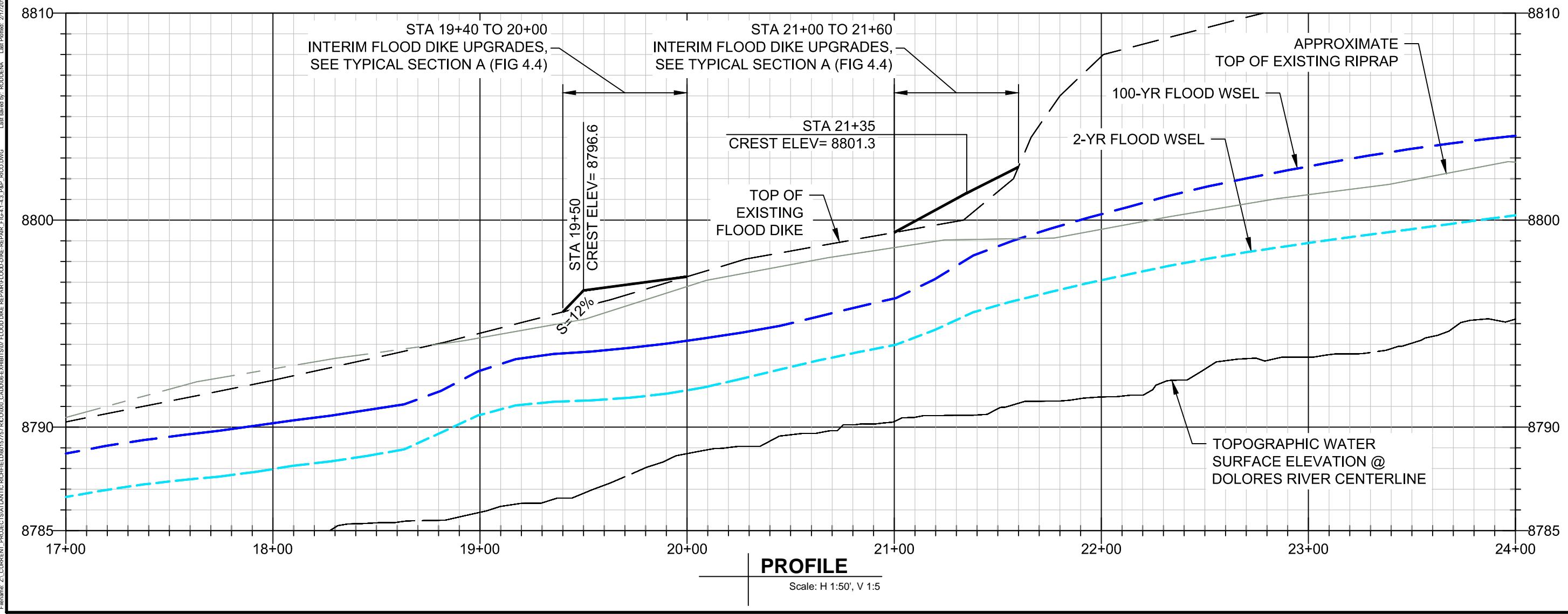
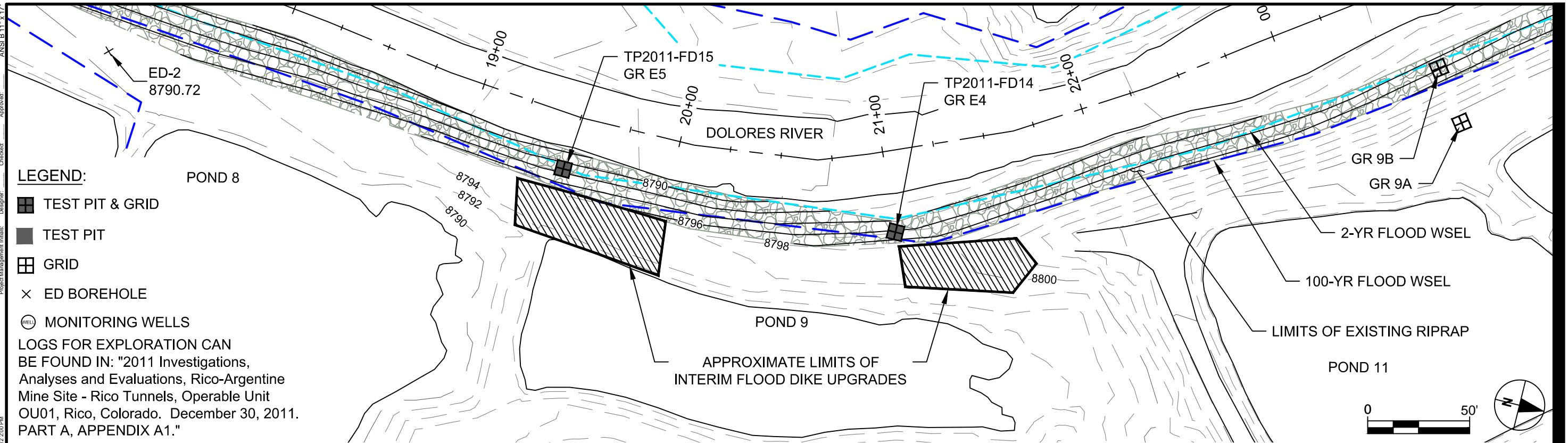
FIGURE 2.4



RICO-ARGENTINE SITE-OU001

INTERIM FLOOD DIKE UPGRADES - PLAN & PROFILE

FIGURE 4.1



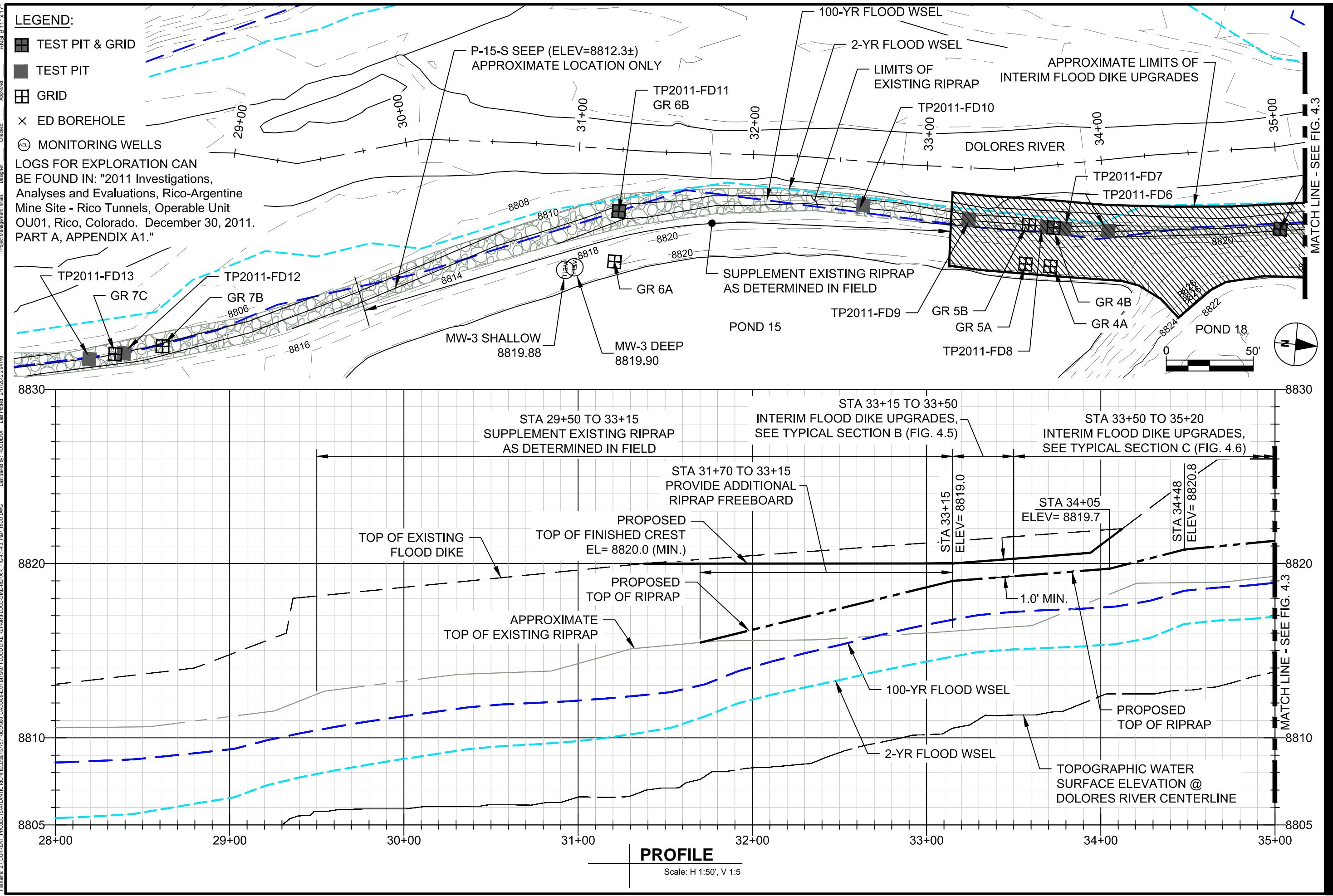
AECOM

60157757

RICO-ARGENTINE SITE-OU01

INTERIM FLOOD DIKE UPGRADES - PLAN & PROFILE

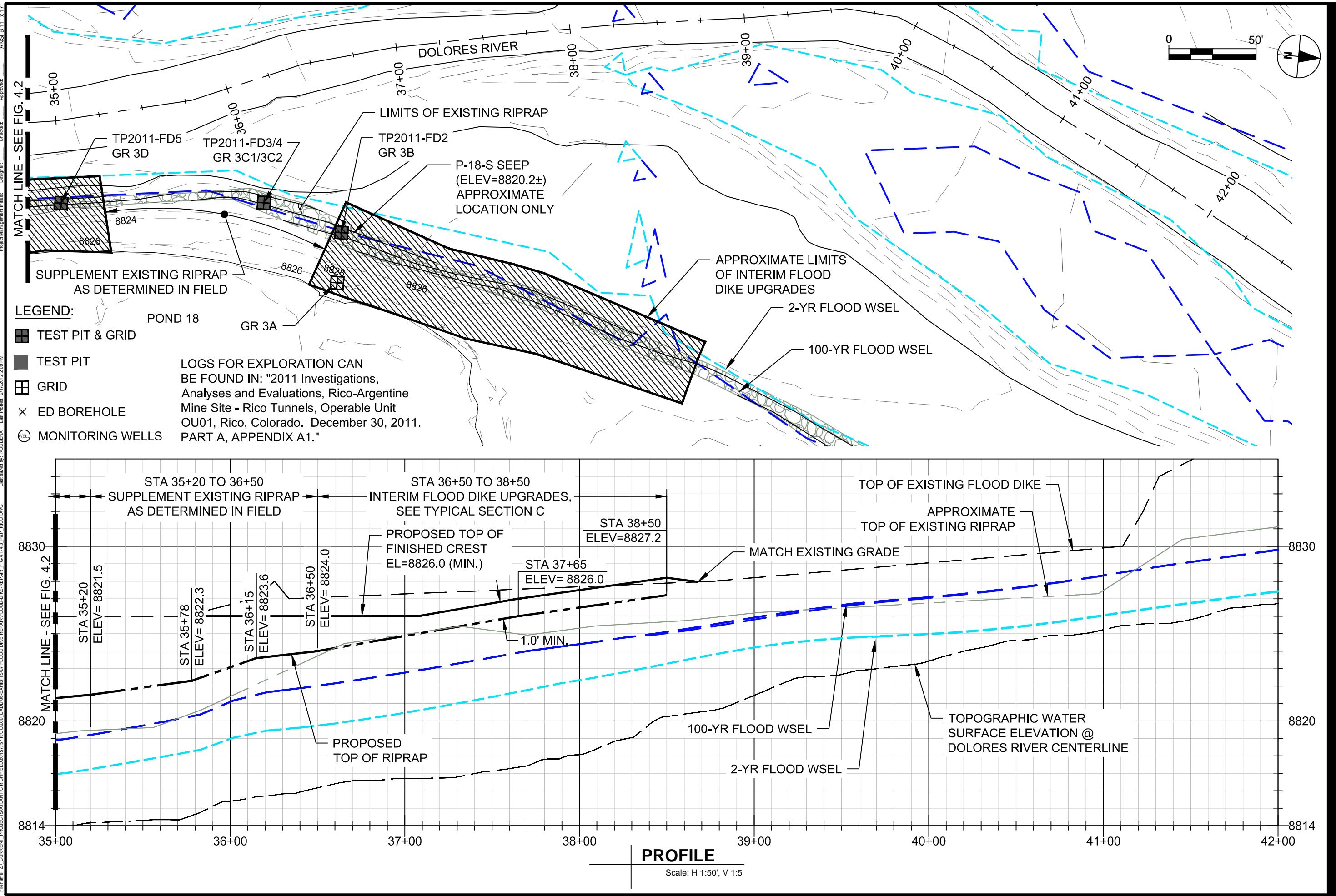
FIGURE 4.2

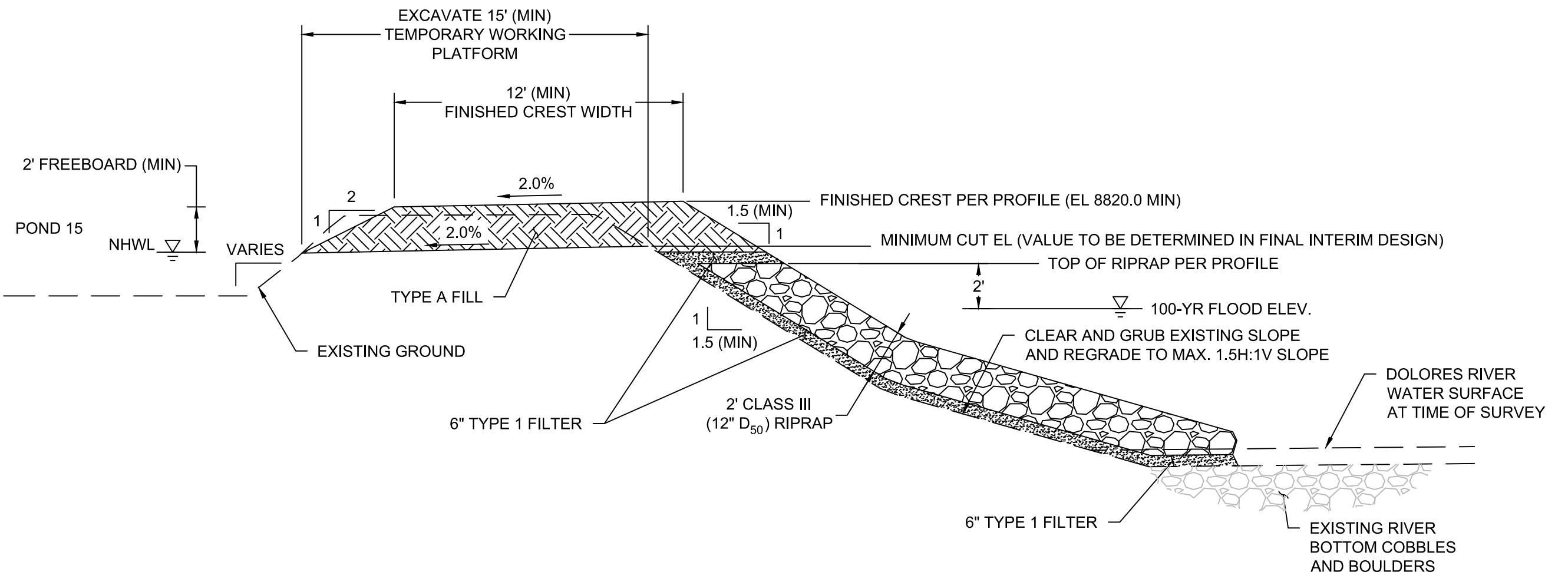


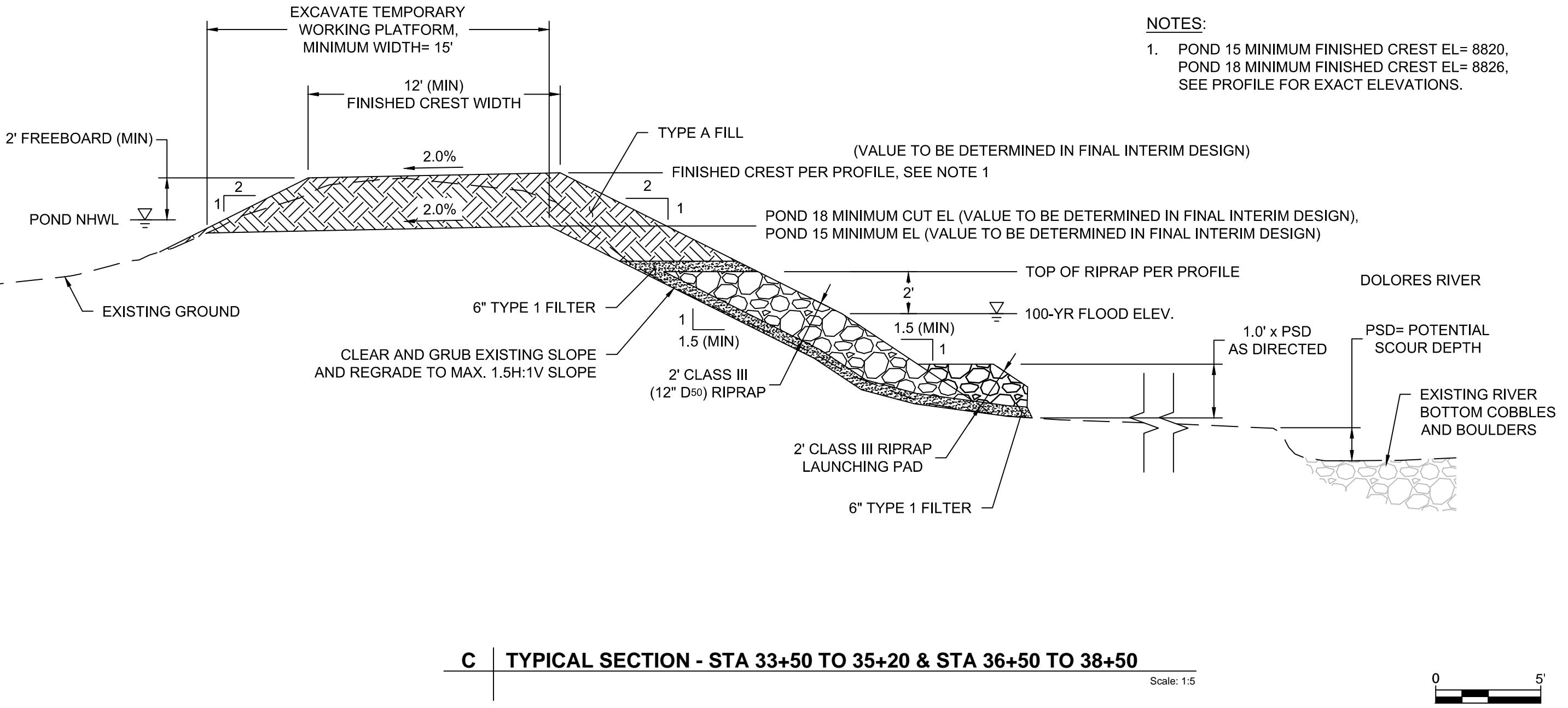
RICO-ARGENTINE SITE-OU01

INTERIM FLOOD DIKE UPGRADES - PLAN & PROFILE

FIGURE 4.3







APPENDIX

Angle of bank in degrees

Station	Theta(degrees)	Slope H:1V
0+00.0	30	1.7
19+50.0	20	2.7
21+00.0	20	2.7
23+72.0	30	1.7
26+47.0	30	1.7
27+95.0	25	2.1
28+61.0	30	1.7
31+25.0	20	2.7
33+55.0	30	1.7
33+65.0	35	1.4
35+00.0	35	1.4
36+00.0	25	2.1
36+50.0	42	1.1
41+00.0	25	2.1
44+50.0	25	2.1
60+00.0	25	2.1

Local Channel Curvature

Channel Type

1 =Natural, 0=Trapezoidal or any number inbetween

Station	U/S Station at beginning of bend		Radius	W	R/W	Vratio(Vss / Vavg)	Vratio Dissipation Rate		Cv	Distance U/s to next bend
	0	113	205				5	1.4	0.00250	
113	113	205	40	40	5	1.0	0.00250	1.1	141	
153	501	9999	40	250		1.0			1.0	
214	501	9999	40	250		1.0			1.0	
254	501	367	40	9	1.2	0.00250	1.1			
501	501	367	40	9	1.0	0.00250	1.1	50		
527	718	9999	40	250		1.0			1.0	
527	718	9999	40	250		1.0			1.0	
552	718	-914	40	-23	1.0	0.00250	1.0			
718	718	-914	40	-23	1.0	0.00250	1.0	82		
758	1076	9999	40	250		1.0			1.0	
760	1076	9999	40	250		1.0			1.0	
800	1076	-664	40	-17	1.0	0.00250	1.0			
1076	1076	-664	40	-17	1.0	0.00250	1.0	114		
1116	1358	9999	40	250		1.0			1.0	
1150	1358	9999	40	250		1.0			1.0	
1190	1358	438	40	11	1.2	0.00250	1.1			
1358	1358	438	40	11	1.0	0.00250	1.1	59		
1388	1618	9999	40	250		1.0			1.0	
1388	1618	9999	40	250		1.0			1.0	
1418	1618	-427	40	-11	1.0	0.00250	1.0			
1618	1618	-427	40	-11	1.0	0.00250	1.0	231		
1658	2269	9999	40	250		1.0			1.0	
1809	2269	9999	40	250		1.0			1.0	
1849	2269	470	40	12	1.2	0.00250	1.1			
2269	2269	470	40	12	1.0	0.00250	1.1	0		
2269	2503	9999	40	250		1.0			1.1	
2270	2503	9999	40	250		1.0			1.0	
2270	2503	-1272	40	-32	1.0	0.00250	1.0			
2503	2503	-1272	40	-32	1.0	0.00250	1.0	459		
2543	3099	9999	40	250		1.0			1.0	
2922	3099	9999	40	250		1.0			1.0	
2962	3099	-355	40	-9	1.0	0.00250	1.0			
3099	3099	-355	40	-9	1.0	0.00250	1.0	152		
3139	3415	9999	40	250		1.0			1.0	
3211	3415	9999	40	250		1.0			1.0	
3251	3415	517	40	13	1.2	0.00250	1.1			
3415	3415	517	40	13	1.0	0.00250	1.1	91		
3455	3608	9999	40	250		1.1			1.0	
3466	3608	9999	40	250		1.1			1.0	
3506	3608	433	40	11	1.2	0.00250	1.1			
3608	3608	433	40	11	1.0	0.00250	1.1	0		
3608	3666	9999	40	250		1.0			1.1	
3608	3666	9999	40	250		1.0			1.0	
3608	3666	-182	40	-5	1.0	0.00250	1.0			
3666	3666	-182	40	-5	1.0	0.00250	1.0	34		
3683	3975	9999	40	250		1.0			1.0	
3683	3975	9999	40	250		1.0			1.0	
3700	3975	-700	40	-18	1.0	0.00250	1.0			
3975	3975	-700	40	-18	1.1	0.00250	1.0	5		
3977	4660	9999	40	250		1.1			1.0	
3978	4660	9999	40	250		1.1			1.0	
3980	4660	600	40	15	1.1	0.00250	1.0			
4660	4660	600	40	15	1.0	0.00250	1.0	202		
4700	4970	9999	40	250		1.0			1.0	
4822	4970	9999	40	250		1.0			1.0	
4862	4970	9999	40	250		1.0	0.00250	1.0		
4970	4970	9999	40	250		1.1	0.00250	1.0	0	
4970	5213	9999	40	250		1.1			1.0	
4970	5213	9999	40	250		1.1			1.0	

4970	5213	627	40	16	1.1	0.00250	1.0	
5213	5213	627	40	16	1.0	0.00250	1.0	-5213

Total Channel Curvature

Channel Type

1=Natural, 0=Trapezoidal or any number inbetween

Station	U/S Station at beginning of bend		W	R/W	Vratio(Vss / Vavg)	Vratio		Cv	Distance	
	Radius					Dissipation	Rate		U/s to next bend	
0	113	205	84	2.4	1.5	0.00119	1.2			
113	113	205	157	1.3	1.5	0.00064	1.3	141		
184	501		192		1.6		1.2			
184	501		192		1.6		1.2			
254	501	367	206	1.8	1.6	0.00048	1.2			
501	501	367	297	1.2	1.0	0.00034	1.3	50		
527	718		312		1.0		1.3			
527	718		312		1.0		1.0			
552	718	-914	328	-2.8	1.0	0.00030	1.0			
718	718	-914	391	-2.3	1.0	0.00026	1.0	82		
759	1076		385		1.0		1.0			
759	1076		385		1.0		1.0			
800	1076	-664	379	-1.8	1.0	0.00026	1.0			
1076	1076	-664	342	-1.9	1.6	0.00029	1.0	114		
1133	1358		337		1.7		1.0			
1133	1358		337		1.7		1.2			
1190	1358	438	336	1.3	1.7	0.00030	1.3			
1358	1358	438	345	1.3	1.0	0.00029	1.3	59		
1388	1618		353		1.0		1.3			
1388	1618		353		1.0		1.0			
1418	1618	-427	362	-1.2	1.0	0.00028	1.0			
1618	1618	-427	293	-1.5	1.3	0.00034	1.0	231		
1734	2269		187		1.4		1.0			
1734	2269		187		1.4		1.1			
1849	2269	470	143	3.3	1.5	0.00070	1.2			
2269	2269	470	78	6.0	1.0	0.00128	1.1	0		
2269	2503		78		1.0		1.1			
2270	2503		78		1.0		1.0			
2270	2503	-1272	78	-16.3	1.0	0.00128	1.0			
2503	2503	-1272	118	-10.7	1.0	0.00084	1.0	459		
2621	3099		99		1.0		1.0			
2806	3099		116		1.0		1.0			
2962	3099	-355	156	-2.3	1.0	0.00064	1.0			
3099	3099	-355	165	-2.1	1.4	0.00060	1.0	152		
3175	3415		161		1.4		1.0			
3175	3415		161		1.4		1.1			
3251	3415	517	167	3.1	1.5	0.00060	1.2			
3415	3415	517	237	2.2	1.6	0.00042	1.2	91		
3461	3608		252		1.6		1.2			
3461	3608		252		1.6		1.2			
3506	3608	433	258	1.7	1.6	0.00039	1.2			

3608	3608	433	272	1.6	1.0	0.00037	1.2	0
3608	3666		272		1.0		1.2	
3608	3666		272		1.0		1.0	
3608	3666	-182	272	-0.7	1.0	0.00037	1.0	
3666	3666	-182	297	-0.6	1.0	0.00034	1.0	166
3749	4043		340		1.0		1.0	
3749	4043		340		1.0		1.0	
3832	4043	-241	377	-0.6	1.0	0.00027	1.0	
4043	4043	-241	273	-0.9	1.4	0.00037	1.0	315
4201	4642		230		1.5		1.0	
4201	4642		230		1.5		1.1	
4358	4642	289	169	1.7	1.6	0.00059	1.2	
4642	4642	289	141	2.0	1.0	0.00071	1.2	220
4752	4970		191		1.0		1.1	
4752	4970		191		1.0		1.0	
4862	4970	-200	224	-0.9	1.0	0.00045	1.0	
4970	4970	-200	162	-1.2	1.4	0.00062	1.0	0
4970	5213		162		1.4		1.0	
4970	5213		162		1.4		1.2	
4970	5213	627	162	3.9	1.4	0.00062	1.2	
5213	5213	627	125	5.0	1.0	0.00080	1.1	-5213

Grid ID: 1
Grid STA: ~ 44+50

			Grid ID: 2		
			Grid STA: 41+00		
Inc.	Cum. Count	Cum Percent	Rock Size	Grid Cell	
0	142	35.50	1'	1	2
23	142	35.50	2' +		1
08	119	29.75	1' - 2'	4	5
21	21	5.25	3" - 1'	49	24
			1/4" - 3"	30%	15%

Adjusted based on photo		
Inc.	Cum.	Cum.
Count	Count	Percent
3	4	
1	153	3
4	151	3
27	134	3
15%	0.7	
10%		

Grid ID:	3C.1
Grid STA:	36+00
	Gr
Rock Size	1
2' +	
1' - 2'	1
3" - 1'	5
0.175 1/4" - 3"	90%
	90%

id Cell		Inc.	Cum.	
		Count	Count	F
	3	4	0	38
			1	38
				37
11	13	33		
84%	82%	3.46		4

Cum Percent	Grid ID: 3C.2
9.42	Grid STA: 36+00
9.42	Rock Size
9.17	Grid Cell
0.92	1
	2
	1'
	1' - 2'
	3" - 1'
	1/4" - 3"
	20%
	10%

Adjusted for fines on surface

fines						
Grid ID: 3A						
Grid STA: 36+50						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
0	8	1.99				
0	8	1.99				
4	8	1.99				
3.6	4	0.99				
fines	10%	10%	8%	8%		

0

-

-

fines						
Grid ID: 3B						
Grid STA: 36+50						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
0	54	13.38				
2	54	13.38				
48	52	12.88				
2.1	4	0.88				
fines	30%	70%	20%	20%		

0

-

-

fines						
Grid ID: 3D						
Grid STA: 35+00						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
0	15	3.72				
0	15	3.72				
11	15	3.72				
3.19	4	0.97				
fines	15%	15%	20%	20%		

0.2

0.20

0.05

fines						
Grid ID: 4A						
Grid STA: 33+65						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
0	25	6.20				
0	25	6.20				
21	25	6.20				
3.49	4	0.95				
fines	10%	10%	5%	5%		

0.97

0.97

0.14

fines						
Grid ID: 4B						
Grid STA: 33+65						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
2'	1			2		
1' - 2'	1	3	1	3		
3" - 1"	5	8	11	15		
1/4" - 3"	83%	79%	78%	70%		
fines	10%	10%	10%	10%		

0

-

-

fines						
Grid ID: 5A						
Grid STA: 33+55						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
3	54	13.38				
8	51	12.63				
39	43	10.63				
3.1	4	0.88				
0.4	0.40	0.10				

0

-

-

fines						
Grid ID: 5B						
Grid STA: 33+55						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
2'	1	1		1		
1' - 2'	2	4	6	5		
3" - 1"	23	13	25	33		
1/4" - 3"	10%	10%	5%			
fines	10%	10%				

0

-

-

fines						
Grid ID: 6A						
Grid STA: 31+25						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
0	17	4.22				
0	17	4.22				
13	17	4.22				
3.52	4	0.97				
0.35	0.35	0.09				

0

-

-

fines						
Grid ID: 6B						
Grid STA: 28+61						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
6	44	11.00				
19	38	9.50				
19	19	4.75				
0	-	-				
0	-	-				

0

-

-

fines						
Grid ID: 7B						
Grid STA: 28+61						
Rock Size	Grid Cell					
Inc.	Cum.	Cum.				
Count	Count	Percent	1	2	3	4
5	51	9.03				
17	46	7.78				
13.33333	29	3.53				
16	16	1.00				
0	-	-				

0

-

-

fines				
Grid ID: 7C		</td		

Safety Factor
 Begin Station
 End Station
 Channel Length
 Channel Type
 g

1.1 = standard; consider larger values if ice or debris impact or uncertainty in design variables
 1100 ft
 4750 ft
 3650 ft
 1=Natural, 0=Trapezoidal or any number inbetween
 32.2 ft/s^2

Local Channel	Total Channel	Riprap Properties	Pavement depth	2	1
			Cohesive limit vel	6	6
			Bed size (in)	6	3

Station	Upstream end of bend	Vavg (ft/s)	Average Velocity (ft/s)	Vratio(Vss/V) (ft/s)	Vss (ft/s)	Station at Upstream end of bend	Vavg (ft/s)	Average Velocity (ft/s)	Vratio(Vss/V) (ft/s)	Vss (ft/s)	Water Surface Elevation (ft)	Min Channel Elevation (ft)	Riprap Analysis	Local Depth of Flow (ft)	Channel Slope (%)	Bank Angle (degrees)	Channel Velocity (ft/s)	Riprap Angularity	Specific Gravity	Stability Coefficient (Cs)	Ct	Velocity Distribution n Coeff (Cv)	Vdesign (ft/s)	Side Slope Correction Factor (K1)	Steep Slop	Ishb ash D30 (in)	d30 (in)	d50 (in)	Scour	MaxScour El	Scour	MaxScour El	Scour El
1100	1244	1.0	5.5	5.8	1194	1.6	4.3	7.8	8777.7	8774	8774	3.9	2.3%	24	5.5	Angular	2.65	0.3	1	1.0	7.8	0.91	6.98	0.0	7.0	8.4	0.0	0.0	8773.8	0.0	0.0	8773.8	
1137	1358	1.0	5.6	5.9	1358	1.6	4.4	8.1	8778.3	8774	8774	3.9	2.3%	24	5.6	Angular	2.65	0.3	1	1.0	8.1	0.91	7.07	0.0	7.1	8.5	0.0	0.0	8774.4	0.0	0.0	8774.4	
1173	1358	1.1	5.7	6.5	1358	1.7	4.5	8.2	8778.9	8775	8775	4.0	2.2%	24	5.7	Angular	2.65	0.3	1	1.0	8.2	0.91	6.99	0.0	7.0	8.4	0.0	0.0	8774.9	0.0	0.0	8774.9	
1210	1358	1.2	5.7	6.8	1358	1.6	4.7	7.8	8779.5	8775	8775	4.1	2.0%	24	5.7	Angular	2.65	0.3	1	1.1	7.8	0.92	6.90	0.0	6.9	8.3	0.0	0.0	8775.4	0.0	0.0	8775.4	
1246	1358	1.1	5.8	6.6	1358	1.4	4.8	7.1	8780.1	8776	8776	4.1	1.9%	24	5.8	Angular	2.65	0.3	1	1.1	7.1	0.92	0.00	0.0	2.9	3.4	0.0	0.0	8775.9	0.0	0.0	8775.9	
1283	1358	1.1	5.8	6.3	1358	1.3	4.9	6.4	8780.7	8776	8776	4.2	1.8%	23	5.8	Angular	2.65	0.3	1	1.1	6.4	0.92	0.00	0.0	2.2	2.6	0.0	0.0	8776.5	0.0	0.0	8776.5	
1319	1358	1.0	5.9	6.1	1358	1.2	5.0	5.7	8781.3	8777	8777	4.3	1.7%	23	5.9	Angular	2.65	0.3	1	1.1	6.1	0.92	0.00	0.0	1.9	2.2	0.0	0.0	8777.0	0.0	0.0	8777.0	
1356	1358	1.0	5.8	5.8	1358	1.0	4.9	5.0	8782.0	8778	8778	4.2	1.7%	23	5.8	Angular	2.65	0.3	1	1.1	5.8	0.93	0.00	0.0	1.7	2.0	0.0	0.0	8777.8	0.0	0.0	8777.8	
1392	1618	1.0	5.7	5.7	1618	1.0	4.8	4.8	8782.7	8779	8779	4.1	1.9%	23	5.7	Angular	2.65	0.3	1	1.0	5.7	0.93	0.00	0.0	1.5	1.8	0.0	0.0	8778.6	0.0	0.0	8778.6	
1429	1618	1.0	5.6	5.6	1618	1.0	4.7	4.8	8783.4	8779	8779	4.0	2.0%	23	5.6	Angular	2.65	0.3	1	1.0	5.6	0.93	0.00	0.0	1.4	1.7	0.0	0.0	8779.4	0.0	0.0	8779.4	
1465	1618	1.0	5.5	5.5	1618	1.1	4.6	5.0	8784.1	8780	8780	3.9	2.1%	22	5.5	Angular	2.65	0.3	1	1.0	5.5	0.93	6.65	0.0	6.7	8.0	0.0	0.0	8780.2	0.0	0.0	8780.2	
1502	1618	1.0	5.4	5.4	1618	1.1	4.5	5.3	8784.8	8781	8781	3.8	2.2%	22	5.4	Angular	2.65	0.3	1	1.0	5.4	0.94	6.65	0.0	6.7	8.0	0.0	0.0	8781.0	0.0	0.0	8781.0	
1538	1618	1.0	5.3	5.3	1618	1.2	4.6	5.8	8785.5	8782	8782	4.0	2.1%	22	5.3	Angular	2.65	0.3	1	1.0	5.6	0.94	0.00	0.0	1.6	7.9	0.0	0.0	8781.5	0.0	0.0	8781.5	
1575	1618	1.0	5.3	5.3	1618	1.2	4.6	5.8	8786.2	8782	8782	4.3	1.9%	22	5.3	Angular	2.65	0.3	1	1.0	5.8	0.94	0.00	0.0	1.5	1.9	0.0	0.0	8781.9	0.0	0.0	8781.9	
1611	1618	1.0	5.2	5.2	1618	1.3	4.7	6.1	8786.9	8782	8782	4.5	1.7%	22	5.2	Angular	2.65	0.3	1	1.0	6.1	0.94	0.00	0.0	1.7	2.0	0.0	0.0	8782.3	0.0	0.0	8782.3	
1648	2092	1.0	5.2	7.0	1783	1.3	4.8	9.3	8787.6	8783	8783	4.8	1.6%	22	5.2	Angular	2.65	0.3	1	1.0	9.3	0.94	0.00	0.0	4.8	5.7	0.0	0.0	8782.8	0.0	0.0	8782.8	
1684	2269	1.0	5.1	5.1	1988	1.4	4.8	6.5	8788.3	8783	8783	5.1	1.4%	21	5.1	Angular	2.65	0.3	1	1.0	6.5	0.95	0.00	0.0	1.9	2.3	0.0	0.0	8783.2	0.0	0.0	8783.2	
1721	2269	1.0	5.1	5.1	2194	1.4	4.9	6.6	8788.9	8784	8784	5.3	1.2%	21	5.1	Angular	2.65	0.3	1	1.0	6.6	0.95	0.00	0.0	2.0	2.4	0.0	0.0	8783.6	0.0	0.0	8783.6	
1757	2269	1.0	5.0	5.0	2269	1.4	5.0	6.8	8789.6	8784	8784	5.6	1.0%	21	5.0	Angular	2.65	0.3	1	1.0	6.8	0.95	0.00	0.0	2.1	2.5	0.0	0.0	8784.0	0.0	0.0	8784.0	
1794	2269	1.0	4.8	4.8	2269	1.4	4.8	6.9	8790.4	8785	8785	5.9	1.1%	21	4.8	Angular	2.65	0.3	1	1.0	6.9	0.95	0.00	0.0	2.1	2.5	0.0	0.0	8784.5	0.0	0.0	8784.5	
1830	2269	1.1	4.7	5.3	2269	1.5	4.7	7.0	8791.2	8785	8785	6.1	1.2%	21	4.7	Angular	2.65	0.3	1	1.0	7.0	0.96	0.00	0.0	2.3	2.7	0.0	0.0	8785.1	0.0	0.0	8785.1	
1867	2269	1.2	4.5	5.7	2269	1.5	4.5	7.0	8792.0	8786	8786	6.4	1.3%	20	4.5	Angular	2.65	0.3	1	1.1	7.0	0.96	0.00	0.0	2.3	2.7	0.0	0.0	8785.6	0.0	0.0	8785.6	
1903	2269	1.2	4.4	5.6	2269	1.4	4.4	6.8	8792.8	8786	8786	6.6	1.4%	20	4.4	Angular	2.65	0.3	1	1.1	6.8	0.96	0.00	0.0	2.1	2.5	0.0	0.0	8786.2	0.0	0.0	8786.2	
1940	2269	1.1	5.2	5.5	2269	1.4	5.2	6.6	8793.3	8787	8787																						

Safety Factor	1 1.1 = standard; consider larger values if ice or debris impact or uncertainty in design variables
Begin Station	1100 ft
End Station	4750 ft
Channel Length	3650 ft
Channel Type	1 1=Natural, 0=Trapezoidal or any number inbetween
g	32.2 ft/s^2

1 1.1 = standard; consider larger values if ice or debris impact or uncertainty in design variables

1100 f

1 = Natural, 0 = Trapezoidal or any number inbetween
33.3 ft/s²

32.2 l/s²

32.2 l/s²

Local Channel

Total Channel

Riprap Properties

Pavement depth
Cohesive limit vel
Bed size (in)

Station	Station at Upstream end of bend				Vavg Average		Station at Upstream end of bend				Vavg Average		Water Surface			Riprap Analysis		Local Depth of Channel			Channel Velocity			Riprap Angularity			Stability Coefficien			Velocity Distributio							
	Vratio(Vss/Vss)	Vavg (ft/s)	Vss (ft/s)	Vratio(Vss/Vss)	Vavg (ft/s)	Vss (ft/s)	Vratio(Vss/Vss)	Vavg (ft/s)	Vss (ft/s)	Min Elevation (ft)	Channel Elevation (ft)	Flow (ft)	Channel Slope (%)	Bank Angle (degrees)	Velocity (ft/s)	Riprap Angularity	Specific Gravity	Coeficien t (Cs)	Ct	n Coeff (Cv)	Vdesign (ft/s)	Distribution Factor (K1)	Side Slope Correction	Steep Slope D30	Ishbash D30	d30 (in)	d50(in)	Scour	MaxScour	Scour El	MaxScour	Scour El					
3473	3608	1.1	3.7	5.0	3608	1.6	3.2	7.1	8818.9	8814	8814	5.3	1.4%	35	3.7	Angular	2.65	0.3	1	1.0	7.1	0.68	0.00	0.0	3.6	4.4	0.0	0.0	8813.6	0.0	0.0	8813.6					
3509	3608	1.2	3.9	5.4	3608	1.6	3.6	7.1	8819.6	8814	8814	5.4	1.5%	34	3.9	Angular	2.65	0.3	1	1.1	7.1	0.71	0.00	0.0	3.6	4.4	0.0	0.0	8814.2	0.0	0.0	8814.2					
3546	3608	1.1	4.1	5.1	3608	1.4	3.9	6.1	8820.2	8815	8815	5.5	1.5%	30	4.1	Angular	2.65	0.3	1	1.1	6.1	0.80	0.00	0.0	2.1	2.6	0.0	0.0	8814.8	0.0	0.0	8814.8					
3582	3608	1.1	4.4	4.8	3608	1.2	4.2	5.1	8820.9	8815	8815	5.5	1.6%	27	4.4	Angular	2.65	0.3	1	1.1	5.1	0.87	0.00	0.0	1.2	1.5	0.0	0.0	8815.4	0.0	0.0	8815.4					
3619	3666	1.0	4.6	4.6	3666	1.0	4.5	4.5	8821.6	8816	8816	5.6	1.6%	31	4.6	Angular	2.65	0.3	1	1.0	4.6	0.78	0.00	0.0	1.0	1.2	0.0	0.0	8816.0	0.0	0.0	8816.0					
3655	3666	1.0	4.2	4.2	3666	1.0	4.1	4.1	8822.2	8817	8817	5.4	2.4%	42	4.2	Angular	2.65	0.3	1	1.0	4.2	0.43	7.46	0.00	7.5	9.0	0.0	0.0	8816.8	0.0	0.0	8816.8					
3692	3975	1.0	3.8	3.8	3783	1.0	3.7	3.7	8822.7	8818	8818	5.1	3.3%	40	3.8	Angular	2.65	0.3	1	1.0	3.8	0.49	7.93	0.00	7.9	9.5	0.0	0.0	8817.6	0.0	0.0	8817.6					
3728	3975	1.0	3.3	3.3	3949	1.0	3.2	3.2	8823.3	8818	8818	4.8	4.2%	39	3.3	Angular	2.65	0.3	1	1.0	3.3	0.55	8.00	0.00	8.0	9.6	0.0	0.0	8818.4	0.0	0.0	8818.4					
3765	3975	1.0	2.8	2.8	4043	1.0	2.8	2.8	8823.8	8819	8819	4.6	5.1%	38	2.8	Angular	2.65	0.3	1	1.0	2.8	0.60	7.75	0.00	7.7	9.3	0.0	0.0	8819.3	0.0	0.0	8819.3					
3801	3975	1.0	2.4	2.4	4043	1.0	2.4	2.4	8824.4	8820	8820	4.3	5.9%	36	2.4	Angular	2.65	0.3	1	1.0	2.4	0.64	7.23	0.00	7.2	8.7	0.0	0.0	8820.1	0.0	0.0	8820.1					
3838	3975	1.1	2.1	2.4	4043	1.0	2.1	2.3	8824.9	8821	8821	4.2	5.9%	35	2.1	Angular	2.65	0.3	1	1.0	2.4	0.68	6.55	0.00	6.6	7.9	0.0	0.0	8820.7	0.0	0.0	8820.7					
3874	3975	1.1	2.1	2.4	4043	1.0	2.1	2.3	8825.5	8821	8821	4.7	3.9%	34	2.1	Angular	2.65	0.3	1	1.0	2.4	0.72	5.65	0.00	5.7	6.8	0.0	0.0	8820.8	0.0	0.0	8820.8					
3911	3975	1.1	2.2	2.5	4043	1.0	2.2	2.4	8826.0	8821	8821	5.1	1.9%	32	2.2	Angular	2.65	0.3	1	1.0	2.5	0.76	0.00	0.0	0.2	0.3	0.0	0.0	8820.9	0.0	0.0	8820.9					
3947	3975	1.1	2.2	2.5	4043	1.1	2.2	2.4	8826.5	8821	8821	5.5	0.0%	31	2.2	Angular	2.65	0.3	1	1.0	2.5	0.79	0.00	0.0	0.2	0.3	0.0	0.0	8821.0	0.0	0.0	8821.0					
3984	4660	1.1	2.3	4.2	4043	1.1	2.3	4.0	8827.0	8821	8821	5.9	-1.5%	29	2.3	Angular	2.65	0.3	1	1.0	4.2	0.82	0.00	0.0	0.8	0.9	0.0	0.0	8821.1	0.0	0.0	8821.1					
4020	4660	1.1	2.4	4.2	4043	1.1	2.4	4.1	8827.5	8822	8822	5.9	-1.1%	28	2.4	Angular	2.65	0.3	1	1.0	4.2	0.85	0.00	0.0	0.7	0.9	0.0	0.0	8821.6	0.0	0.0	8821.6					
4057	4660	1.1	2.6	4.1	4095	1.1	2.6	4.2	8828.0	8822	8822	6.0	-0.7%	27	2.6	Angular	2.65	0.3	1	1.0	4.2	0.87	0.00	0.0	0.7	0.9	0.0	0.0	8822.0	0.0	0.0	8822.0					
4093	4660	1.1	2.7	4.1	4238	1.2	2.7	4.3	8828.4	8822	8822	6.0	-0.4%	25	2.7	Angular	2.65	0.3	1	1.0	4.3	0.89	0.00	0.0	0.8	0.9	0.0	0.0	8822.4	0.0	0.0	8822.4					
4130	4660	1.1	2.8	4.1	4381	1.2	2.8	4.5	8828.9	8823	8823	6.1	0.0%	25	2.8	Angular	2.65	0.3	1	1.0	4.5	0.90	0.00	0.0	0.8	1.0	0.0	0.0	8822.8	0.0	0.0	8822.8					
4166	4660	1.1	3.0	4.1	4524	1.3	3.0	4.7	8829.4	8823	8823	6.1	0.3%	25	3.0	Angular	2.65	0.3	1	1.0	4.7	0.90	0.00	0.0	0.9	1.1	0.0	0.0	8823.3	0.0	0.0	8823.3					
4203	4660	1.1	3.1	4.0	4642	1.3	3.1	4.8	8829.9	8824	8824	6.2	0.7%	25	3.1	Angular	2.65	0.3	1	1.0	4.8	0.90	0.00	0.0	1.0	1.1	0.0	0.0	8823.7	0.0	0.0	8823.7					
4239	4660	1.1	3.2	4.0	4642	1.3	3.2	4.8	8830.5	8824	8824	6.3	0.6%	25	3.2	Angular	2.65	0.3	1	1.0	4.8	0.90	0.00	0.0	1.0	1.1	0.0	0.0	8824.2	0.0	0.0	8824.2					
4276	4660	1.1	3.4	4.0	4642	1.3	3.4	4.8	8831.2	8825	8825	6.5	0.3%	25	3.4	Angular	2.65	0.3	1	1.0	4.8	0.90	0.00	0.0	1.0	1.2	0.0	0.0	8824.7	0.0	0.0	8824.7					
4312	4660	1.1	3.5	4.0	4642	1.4	3.5	5.1	8831.8	8825	8825	6.7	-0.1%	25	3.5	Angular	2.65	0.3	1	1.0	5.1	0.90	0.00	0.0	1.1	1.3	0.0	0.0	8825.2	0.0	0.0	8825.2					
4349	4660	1.1	3.3	3.9	4642	1.5	3.3	5.4	8832.8	8826	8826	7.0	-1.1%	25	3.3	Angular	2.65	0.3	1	1.0	5.4	0.90	0.00	0.0	1.2	1.5	0.0	0.0	8825.8	0.0	0.0	8825.8					
4385	4660	1.1	3.0	3.9	4642	1.4	3.0	5.3	8833.9	8827	8827	7.4	-2.5%	25	3.0	Angular	2.65	0.3	1	1.0	5.3	0.90	0.00	0.0	1.2	1.4	0.0	0.0	8826.5	0.0	0.0	8826.5					
4422	4660	1.0	2.6	3.9	4642	1.4	2.6	5.1	8835.0	8827	8827	7.8	-4.0%	25	2.6	Angular	2.65	0.3	1	1.0	5.1	0.90	0.00	0.0	1.0	1.3	0.0	0.0	8827.3	0.0	0.0	8827.3					
4458	4660	1.0	2.7	3.9	4642	1.3	2.7	4.9	8835.8	8829	8829	7.3	-2.2%	25	2.7	Angular	2.65	0.3	1	1.0	4.9	0.90	0.00	0.0	1.0	1.1	0.0	0.0	8828.5	0.0	0.0	8828.5					
4495	4660	1.0	2.8	3.8	4642	1.2	2.8	4.6	8836.5	8830	8830	6.6	0.0%	25	2.8	Angular	2.65	0.3	1	1.0	4.6	0.90	0.00	0.0	0.9	1.0	0.0	0.0	8829.9	0.0	0.0	8829.9					
4531	4660	1.0	2.9	3.8	4642	1.2	2.9	4.4	8837.2	8831	8831	6.0	2.2%	25	2.9	Angular	2.65	0.3	1	1.0	4.4	0.90	5.95	0.00	5.9	7.1	0.0	0.0	8831.3	0.0	0.0	8831.3					
4568	4660	1.0	3.1	3.8	4642	1.1	3.1	4.2	8838.2	8833	8833	5.6	3.4%	25	3.1	Angular	2.65	0.3	1	1.0	4.2	0.90	7.45	0.00	7.5	8.9	0.0	0.0	8832.6	0.0	0.0	8832.6					
4604	4660	1.0	3.3	3.8	4642	1.1	3.3	4.0	8839.4	8834	8834	5.5	3.2%	25	3.3	Angular	2.65	0.3	1	1.0	4.0	0.90	7.56	0.00	7.6	9.1	0.0	0.0	8833.9	0.0	0.0	8833.9					
4641	4660	1.0	3.6	3.7	4642	1.0	3.6	3.7	8840.7	8835	8835	5.4	3.1%	25	3.6	Angular	2.65	0.3	1	1.0	3.7	0.90	7.63	0.00	7.6	9.2	0.0	0.0	8835.3	0.0	0.0	8835.3					
4677	4792	1.0	3.4	3.4	4802	1.0	3.4	3.4	8841.7	8836	8836	5.6	2.1%	25	3.4	Angular	2.65	0.3	1	1.0	3.4	0.90	6.23	0.00	6.2	7.5	0.0	0.0	8836.1	0.0	0.0	8836.1					
4714	4970	1.0	2.8	3.9	4970	1.0	2.8	3.9	8842.6	8836	8836	6.2	0.3%	25	2.8	Angular	2.65	0.3	1	1.0	3.9	0.90	0.00	0.0	0.5	0.6	0.0	0.0	8836.4	0.0	0.0	8836.4					
4750	4970	1.0	2.1	3.9	4970	1.0	2.1	3.9	8843.5	8837	8837	6.8	-1.6%	25	2.1	Angular	2.65	0.3	1	1.0	3.9	0.90	0.00	0.0	0.5	0.6	0.0	0.0	8836.7	0.0	0.0	8836.7					

Neill Competent velocity

Interpolation table

bed	Log Bed Size (ft)	depth (ft)	Comp Mean Vel (ft/s)
0.001	-3	2	1.5
0.001	-3	5	2.2
0.001	-3	10	3.2
0.001	-3	20	4.6
0.001	-3	50	7
0.01	-2	2	2.7
0.01	-2	5	3
0.01	-2	10	4.5
0.01	-2	20	5.8
0.01	-2	50	8
0.1	-1	2	6.1
0.1	-1	10	8
0.1	-1	20	9
0.1	-1	50	11
1	0	2	13.12
1	0	10	16.564
1	0	50	22.96
Test Interpolation	1	0	20
			19.85425

